ADOPTING SUSTAINABLE INNOVATIONS

A Case on Renewables' Integration into the Grid

A THESIS SUBMITTED TO THE FACULTY OF THE UNIVERSITY OF MINNESOTA BY

Barbara Jean ("BJ") Allen

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENGINEERING MANAGEMENT

ADVISER: DR. HONGYI CHEN

May 2019

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Acknowledgments

This work was supported in part by the University of Minnesota – Duluth QMA Scholarship.

Many thanks for the incredible support of Dr. Hongyi Chen who bent over backwards to help me, and without whom this opportunity would not have been remotely possible. Additional gratitude goes to my committee members, Dr. Wenqing Zhang, and Dr. Robert Feyen, who kindly dedicated time to this effort out of their busy schedules.

I appreciate everyone's contributions: your advice and expertise resulted in a superior product.

Dedication

Inexpressible gratitude to the amazing, wonderful, supportive love of my life and kindred spirit in this confusing world, Jason Edens.

Abstract

Disruptive changes are impacting the electric utility industry worldwide as an increasing amount of renewably generated electricity contributes to grid supply to combat negative environmental impacts of traditional electricity production. The U.S. utility companies are protected natural monopolies faced with an increasing power generation competition and decreasing revenue as a result. As the industry transitions over the coming decade, the ability to thrive will be dependent upon the incumbents' ability to adapt while continuing to grow existing technological competencies. How to further promote renewable energies in the monopoly market and how can the U.S. electric utilities successfully adapt in such an environment are the main research questions this thesis attempts to answer. Based on literature review, five specific questions were developed and then investigated using the case study on a uniquely innovative leader in the utility industry--Green Mountain Power of Vermont. Results show that a natural monopoly can be effective in promoting sustainable innovations given the right environment. Among the many factors that influence the adoption of sustainable innovations in a natural monopoly market, regulation plays a critical role. Incumbents with a corporate culture which enables strategic change, and those able to incorporate sustainable innovations into their business model will be less likely to be disrupted by the changes occurring in the market. Monopoly incumbents recognizing and pursuing new market opportunities arising out of sustainable innovations, rather than viewing the change as disruptive, will be more likely to contribute to the successful diffusion of such innovation.

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1.0 Introduction

The climate is changing rapidly as a result of the anthropogenic emissions of greenhouse gases [1]. The most significant source of global greenhouse gas emissions is the production of electricity from fossil fuels [2]. Even if all emissions were to immediately halt, global temperatures are predicted to rise by at least 1.5^{o}C [1]. Electricity production in the U.S. made up 35% of total CO_2 emissions in 2016, with 98% of those emissions derived from coal (68%) and natural gas (30%) [3]. Meanwhile, the world's total electricity consumption is projected to rise an average of 1.9% per year in non-Organization for Economic Cooperation and Development (OECD) countries between 2015 and 2040, with growth fueled in part by a transition from fossil-fuel based locomotion to electric vehicles [4].

The urgency of transitioning to a sustainable means of electricity production requires the rapid adoption and diffusion of sustainable technological solutions. The adoption of these solutions could be a critical component in preventing extreme climate change [5]. Renewable distributed generation is a modern technological solution to traditional polluting electrical power production that could be rapidly adopted. And yet despite significant double-digit growth over the past few years relative to its starting point, renewable energy (RE) still only comprises a small portion of worldwide electricity supply [4]. The integration of renewables into existing grids will be required in order to achieve the high level of integration forecasted – and reduce carbon emissions to avert the increasing impacts of climate change.

The incorporation of renewable energy into the electric grid is a unique disruptive situation – unlike a more typical disruptive technology, in and of itself, solar energy and other renewables will not eliminate a customer's need for the grid, or at least some other source of power that can provide for electricity needs during periods of clouds, night, or lack of wind. Yet the nature specifically of solar in facilitating independent consumer possession of power plants will transform the utility grid and the interactions of utilities and their customers. As with any disruptive innovation, incumbent utilities fight competition through preventing integration, creating hurdles for interconnection, lobbying policymakers, or through other mechanisms.

Due to regulatory and technological changes which continue to increase renewable competition on the grid while lowering per capita demand for utility-produced energy, electric utilities are facing a disruptive transition that will change the way in which they operate. It is well established in the literature that many incumbent firms have failed to react appropriately in the face of innovation. History demonstrates that some incumbents are able to adapt, while others decline and die. Christensen discusses the following reasons: companies follow their own value network, companies fail to anticipate new technological innovations, and companies ignore new entrants [6].

A few utilities, however, are proactively preparing for the paradigm shift, and thoughtfully adapting in order to continue to be relevant. This work reflects on a unique electric utility taking an active role in innovating as a potential example to others. For utilities interested in self-preservation, understanding how best to adapt to their changing market is critical.

The adoption of renewable energy into the existing electricity grid presents a variety of challenges, ranging from policy to social to technical issues. In the U.S., 100% of U.S. residents is considered to have access to grid electricity [7], so practically speaking no one is outside of the reach of the utility electric grid. Historically the central electric grid as well as the generation and distribution system is controlled by utilities, and utilities organized as Investor Owned Utilities (IOUs) provide electricity to the majority (73%) of the U.S. population [8]. Therefore, the barriers to diffusion focused on for this paper are those resulting from the IOUs.

Many articles discuss the energy transition occurring worldwide [9] [10], and there is extensive research examining successful and unsuccessful reactions of companies during periods of transition [6] [11]. There is very little research examining the adoption and diffusion of sustainable innovations by monopolies. Having identified key barriers to the diffusion of the specific innovation of renewable energy, this thesis focuses on the entity with the most potential to act as a driver or barrier to the rapid diffusion of solar energy: monopolistic investor owned utilities, as owners and operators of the distribution channel. This thesis investigates unique factors impacting the adoption of sustainable innovations, and innovation in monopoly markets.

Section 2 includes a literature survey of the diffusion of innovation as well as the diffusion of sustainable innovations including unique barriers, and innovation in monopoly markets. Section 3 details five research questions generated based on literature review, which are later investigated in section 4 through a case study on Green Mountain Power of Vermont. Section 5 provides a conclusion.

2.0 Literature Survey

2.1 The Diffusion of Sustainable Innovations

Distinct from invention, innovation implies market success which requires making and taking opportunities. There is significant interest in innovations, since adoption of innovations directly impact a company's success [12]. Investments in innovations have shown more than 50% social rate of return, and about 25% financial rate of return [13]. The life cycle of innovation follows a predictable pattern in the marketplace from early problems as the technology is being developed, to the emergence of a dominant design as the technology itself evolves less but manufacturing and other processes are still improving, and ultimately leads to replacement as new superior technologies emerge. The idea, or invention, is only one small part of the life cycle, at the very beginning of a long road to innovation. Many innovations succeed, while many ideas die. Consumer demand, technical feasibility, economic and engineering practicability, needed resources available to develop the technology, and the initiative to pull everything together are forces frequently present in successful commercialization of innovations [14]. Opportunities for new innovations arise when gaps occur in markets, caused by changing customer preferences, advancing technologies, altering government policies, etc.

With respect to speed of diffusion, Rogers described the trajectory of an innovation adopted in society as following an S-curve, with the innovation taking off slowly, gaining momentum, maturing, decelerating, and eventually being discontinued. This framework can be strategically helpful for organizational decision-makers [15]. In terms of the distribution of adopters in society, Rogers presented the notion that the distribution of the diffusion of innovations occur according to a normal-distribution bell curve. According to Rogers, of all adopters, 2.5% are the first to adopt and willing to accept some flaws and/or greater expense, known as Innovators. The next set of adopters, consisting of 13.5% of the total adopters, are still willing to accept some product limitations given the set of advantages offered over other products in the marketplace and help to spread the technology throughout their social network. Early majority adopters consist of 34% of the total and come on board once the innovation has been through multiple iterations and advances, and having deliberated about the innovation. Late majority adopters comprise 34%, and finally the laggards, making up 16% of the total, decide to adopt the innovation [16] [17]. Figure 1 below depicts the adoption curves described in the Rogers model.

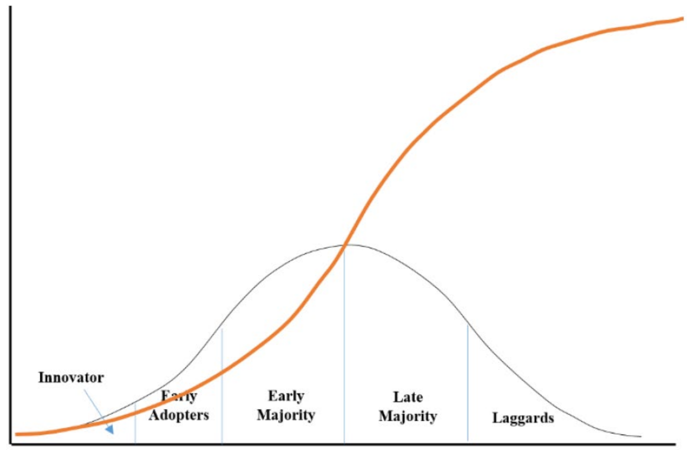

Figure 1: Adoption S-curve trajectory vs. Adopter Categories [18]

Broadly, the diffusion of innovation and the speed of that diffusion are impacted by several key factors, including:

1. The new product offers comparative **advantages** over an existing product.
2. The new product is **compatible** with existing cultural norms.
3. The new product is readily understood by users (**complexity**).
4. The new product can be easily tested and **tried**.
5. The new product has apparent and **observable** benefits [19].

The same factors that impact innovation listed above similarly contribute to the diffusion of sustainable innovations. Of particular impact in the adoption of sustainable innovations are compatibility with existing cultural norms and user acceptance. Sustainable innovations that require broader cultural change, or are closely linked to other activities, take much longer to diffuse or may not achieve diffusion [20].

Sustainable innovations are a specific sort of innovation, with similar key factors influencing the speed of the diffusion, yet with distinct barriers and advantages to adoption. According to Albert Little, "'sustainability-driven' innovation means the creation of new market space, products & services or processes driven by social, environmental or sustainability issues" [21]. Pursuit of sustainable innovations could lead a firm to discover new business opportunities, to offer products or services that are beneficial to both the company and society, and to enter into business offerings with increased endurance, by definition. The survey of 40 technology firms in 2004 representing Japan, the U.S., and Europe in Little's study found that 95% of businesses believe sustainability-driven innovation will likely deliver business value, while almost 25% were certain it would produce business value. The potential value sustainable innovations delivers goes beyond direct revenue, as it further serves to enhance reputation and brand value according to 80-90% of the surveyed companies [21].

There are of course challenges to incorporating sustainable innovations into a firms' business model. As identified by Long et al., barriers include economic, regulatory, psychological, organizational, market, and social. Firms are often hampered in adopting sustainable innovations by their own internal business processes [5]. In order to be successful at deploying sustainable innovations, a company must behave differently, including leadership, company principles and processes, collaboration, and focus on the customer [21].

The primary barrier identified for the adoption of sustainable innovations inside a company is that it would require a change in the corporate mindset [22]. The same high barriers are encountered throughout society, as oftentimes sustainable innovations face sociotechnical evolution [23]. Sociotechnical transitions involve a web of many interdependent actors, thereby favoring incremental innovations and discouraging radical innovations. Incremental innovations improve existing technologies, while radical innovations are discontinuous, potentially resulting in significant changes for the entire network [23].

Early adoption of sustainable innovations is particularly impacted by three attributes: instrumental, environmental, and symbolic [24]. The instrumental attribute refers to the perceived working impact of the sustainable innovation, the environmental attribute refers to the perceived ecological effect of the sustainable innovation, and the symbolic attribute refers to the perceived related character and societal prestige. These three attributes successfully predicted the adoption of current popular sustainable innovations which are publicly obvious like electric cars, as well as ones which are less noticeable, like renewable energy [24].

The market has long been focused on short-term investments and gains. As a result, innovating for the long-term requires rethinking strategies [25] and expanding beyond existing institutional knowledge. Societal impact needs to be accounted for in the adoption and diffusion of sustainable innovations, as they often have a broader impact on society. Existing market forces may oppose sustainable innovations. Policies may not support the innovations. There may not be accreditation available for the new technology, or there may be subsidies in place for competing technologies that are not available for the innovations [5].

Barriers to adopting sustainable innovations for agriculture in Europe were identified by Long et al., and summarized in Table 1. Although this study focused on agriculture, the barriers and the details both follow for other sustainable innovations. Analogous barriers are identified in the text below to the diffusion of solar energy. Table 1 neatly summarizes findings explored in the text for the barriers to the diffusion of sustainable innovations. These broadly include economic, institutional/regulatory, behavioral/psychological, organizational, consumer/market, and social factors.

Table 1: Barriers to the Diffusion of Sustainable Innovations [5]

Barrier	**Detail**	**Sources**
Economic	High initial investments	[27-36]
	Poor access to capital	
	Hidden costs	
	Competing financial priorities	
	Long payback periods (ROI)	
	Switching costs/existence of installed base	
	High implementation costs (actual and perceived)	
	Uncertain returns and results	
	Temporal asymmetry between costs and benefits	
	Over discounting the future	
Institutional/ Regulatory	Low institutional support	[25] [26] [27] [28]
	Use of overly scientific language (jargon)	
	Practitioners' knowledge gained from experience not considered R&D	
	Lack of regulatory framework	
	Prohibitively prescriptive standards	
Behavioral/ Psychological	Lack of management support/awareness	[29] [30] [37-41]
	Conflict with traditional methods	
	Overly complex technologies	
	Results/effects of technology difficult to observe	
	Practitioners' beliefs and opinions	
	Low trust of advisers or consultants/lack of acceptance	
	Irrational behavior	
	Negative presumed assumptions	
Organizational	Lack required competencies/skills	[25] [29] [31] [32] [27] [33]
	Poor readiness	
	Poor information	
	Inability to assess technologies	
	Overly short-term/perverse rewards focus	

	Organizational inertia/habitual routines	
Consumers/ Market	Poor information	[26] [29] [34] [27] [33] [35]
	Lack market attractiveness/do not align to preferences	
	Uncertainty	
	Consumers/farmers level of motivation	
	Market uncertainty	
Social	Social/peer pressures	[25]

Identified in Table 1 above, societal influences on the adoption of sustainable innovation can be significant. One human trait that negatively impacts the prioritization of sustainable innovations is the tendency of people to discount the future. In a study of the psychology and sociology of adoption of sustainable building practices [36], researchers found that individuals tended to view the future in a rosy as opposed to realistic light [37], which negatively impacted adoption rates. Individuals also stereotyped others who adopted sustainable building practices as part of liberal culture [38], which further impacted adoption rates [5].

Sustainable innovations diffuse more readily if they are in alignment with existing practices [45-52]. Elements within a practice may be loosely or heavily dependent on one another. Loose linkages will result in little if any observable change, while tight linkages will generate disruption. For example, switching from incandescent to more efficient light emitting diode bulbs, there is little change in the light that is generated, aesthetics or ambience, and therefore linkages are loose. Loose linkages are more likely to be quickly adopted. For adoption of sustainable innovations where heavily dependent elements are at play, behavior modification is often slow, for example shorter showers for water conservation or laundering clothes at low temperatures. Tight linkages between elements where the sustainable innovation is attempting to gain hold result in slower adoption [20]. In the adoption of grid-tied solar energy, the linkage for individual consumers is loose. The individual notices no difference in the use or convenience of their electric systems, since they behave exactly as before. However, the linkage for electric utilities is tight and distributed generation creates disruption, resulting in slower adoption.

Since in most situations where sustainable innovations are created, needs are already being met through existing products, the uptake of sustainable innovations requires transforming needs, as opposed to meeting them [20]. In the case of renewable energy, policy helps to instigate transformation by setting up protected spaces for niche technologies to thrive. Research conducted on strategic niche management and the uptake of PV in the UK found that protected places for sustainable technologies was necessary for the innovation to develop to the point of being able to compete in the open market setting. The study found that these protected spaces are fashioned by society and notably, therefore disputed politically [39].

The diffusion of distributed generation such as solar energy as a sustainable innovation in the energy sector faces its own unique set of barriers. Factors contributing to higher early adoption rates of solar energy at the individual level include greater awareness or knowledge, and a lack of sensitivity to cost. Other contributing factors to adoption include energy cost savings and word-of-mouth [40]. While advantages relative to the incumbent technology, such as cost, are important factors in the adoption of photovoltaics, social and psychological factors including environmental awareness and prestige also significantly impact adoption [41].

2.2 Innovating in a Monopoly Market

In the interest of self-preservation, established companies have a vested interest in being innovative. Yet, strategic innovations typically result from new entrants as opposed to established companies [42]. Incumbents often do not innovate in the interest of preserving the status quo, due to existing structure or culture, and an unwillingness to abandon the profitable present for an uncertain future [42]. In his study of disruptive innovations, Christensen believes that established companies could also fail because they follow their own value network, stay too close and listen exclusively to the main stream customers, ignoring new entrants which eventually disrupt the established companies [6].

2.2.1 Innovation in monopoly markets

In 1943, Joseph Schumpeter argued that monopolies are uniquely able to accelerate innovation by virtue of their available resources to fund research and development [43]. Adolf and Gardiner on the other hand, argued in 1932 that monopolies are less likely to innovate due to structural rigidity [44]. Later on, identifying competition as the primary impelling cause behind innovation, Arrow maintained that monopolies are less likely to innovate due to the lack of competition in a monopoly market [45]. A diverse set of studies since has sought to determine how competition impacts innovation, with nuanced results. Examining innovation from the perspective of research and development (R&D) spending, Loury determines that “perfect” competition decreases R&D spending on an individual basis, but still results in a higher likelihood that society will have a reduced wait time for innovation to occur. He determines the ideal amount of competition lies directly in between Adam Smith’s pure competition where monopolies are limited and R&D performance is the highest, and Schumpeter’s momentary monopolies as part of a natural evolution that eventually get eroded as competition, replication, and innovation arise [46]. Cohen and Levin found that research over time had broadened from a focus on size and market concentration to other determinants of innovation. They further showed that patent data is not necessarily indicative of innovation, as patent protection varies wildly between different industries [47]. Gilbert determined that monopolies do not promote innovation, yet also found that competition does not necessarily promote innovation either. His research found weak links between, and no optimal level of competition and R&D [48]. A recent study of U.S. patent data combined with companies' productivity, however, demonstrated a clear positive relationship between competition and innovation [49].

Under the condition of intense competition, there are greater incentives for both product and process innovations. Incentives to innovate in process for protected monopolies directly correlate to the profits a firm can protect or earn by innovating. If a new product renders the existing product obsolete, the incentive to innovate would be high in a competitive marketplace. If the new product does not render the existing product obsolete (non-drastic innovation), the incentive to innovate would be less [48].

For monopolies, there is a clearer incentive to engage in process innovations, as these could result in a healthier bottom line by improving efficiency. However, an innovative product would compete with an existing offering. Revenue generated by a new product would result in a loss from the old technology, thus de-incentivizing innovation through the loss of extant profits, coined the "replacement effect" [50]. The monopoly continues to enjoy profits regardless of whether or not it innovates [51] and this appears especially true for a regulated rate-of-return monopoly. Rate-of-return monopolies have even less reason to innovate as they have guaranteed customers and further guaranteed set profit. However, a monopoly could potentially benefit more from a new product by differentiating offerings with customers, compared to a competitor with only the new product to offer customers [52]. A clear example of this is a competitor who is offering a new product in the distributed generation (DG) market, IPPs. Partial deregulation facilitated the ability of IPPs in some instances to sell renewably-sourced and/or lower-cost power directly to consumers. Any consumers participating in this scheme will still rely on backup power through the monopoly utility. Since the competitor in this case only has the new product, DG power, to offer, the monopoly could potentially benefit more by offering customers the whole package, including DG. Yet it is unclear what the payback would have to be in order for monopolies to risk offering a new product as compared to maintaining the status quo.

Segments of the private sector are poised to adopt innovations quickly and respond better to market changes. The incentive for a monopoly to innovate depends upon the difference in benefit with and without the innovation. If the benefit is high, there may be incentive to innovate. If the benefit is unclear or low, then the costs of innovation and the failure rates of innovation may outweigh any incentive to innovate. Innovation is risky [53] and determining potential benefits of an innovation in advance can be challenging at best. Risk assessments, including benefit to customers, required resource allocation, market timing and other variables, attempt to predict those benefits compared to innovation costs [54]. Part of the risk assessment is understanding innovation successes to begin with, which by one measure is the number of marketplace failures, accounting for close to 90% of ideas [55]. Failure is as inevitable as innovation. Most new ventures fail, the majority of products don't succeed, and most startups also fail [56].

Other determinants to innovation are organizational in nature. Corporate culture is key – successful innovators develop a culture that encourages experimentation and discontent with the status quo. This sort of innovative mind-set is often challenging for incumbents to generate and indeed may be in conflict with a general attitude of satisfaction with the status quo [42].

IOUs are organized as rate-of-return regulated monopolies in many countries including the U.S.. By being granted a specific customer base they are required to serve, they are also guaranteed a reasonable rate of return in exchange. In his study of the utility industry, Mark Frank found that the principal weakness of rate-of-return monopolies was the negative impact this organizational structure had on technological innovation [57]. Another study found incremental innovation at work in monopolistic utility structures, with accompanying incremental change. This study found that when the utility market was deregulated, increased competition broke down barriers to radical innovation for the incumbents [58].

The movement towards deregulation in the electric sector around the world in recent decades opened up opportunities to examine the impacts of increased competition in the marketplace on innovations. The electric utility industry is unique in that much of the R&D in the regulated rate-of-return monopolistic marketplace has been focused on activities which are in the public's interest but do not advance the long-term financial benefit of the company, such as energy efficiency initiatives. Wang and Mogi studied the impact of deregulation on the Japanese electric sector, which is in alignment with similar efforts elsewhere in the world, that took place in year 2017 [58].

Wang and Mogi found that the effects of deregulation and competition in the Japanese electric utility market resulted in reduced R&D expenditures, but increased patent activities, which could be an indicator of the company's innovation capability. However, with a deregulated marketplace, unprotected intellectual property that was not beneficial under the regulated marketplace may become more valuable for new competition, thus incentivizing patent activity but not necessarily indicating innovation. Further, short-term gains in R&D efficiency accompanied by a reduction in R&D expenditures may eventually result in long-term negative impacts on innovation, an idea that has been shown to be the case in both the US by Sanyal and Cohen [59], and the UK by Jamasb and Pollitt [60].As a conclusion, Wang and Mogi stated that:

> “Innovation in the electricity industry exhibits strong path dependence. Therefore, at incumbent utilities, we find incremental innovation, which builds high barriers for radical change” [58].

Deregulation prompted innovation in the EU electric utility market according to Markard and Truffer [61], and similarly occurred in the liberalization of the Japanese market. R&D expenditures were maintained in areas that had the potential to cut costs and therefore increase profits, but not in efforts beneficial to the public at-large that would reduce utility revenue, such as renewable energy or energy efficiency [58]. Utility generation mix also has an impact on R&D expenditures, with utilities sourcing their power in part from nuclear demonstrating higher R&D expenditures [59] [76-78]. This effect was particularly notable in the Japanese market following the Fukushima nuclear meltdown.

As it may be difficult or impossible for new entrants to enter a market dominated by monopolies, pathways exist for innovations to happen in a market dominated by monopolies by effectively utilizing the platforms and/or distribution channels created by the monopolies. Using the platform strategy, monopolies can drive innovations without taking risks themselves. Companies that have successfully created platforms won out over those that tried to internally manage innovation. The Blackberry and iPhone had similar features, but the Apple app store platform provided added value to the iPhone where developers could feature their innovations. The app store provides a platform for all the app developers to develop and distribute their programs (apps) through its distribution channel, ultimately contributing to the success of Apple. Another example is the Amazon monopoly that provides a distribution channel for small businesses to sell on its platform [62].

A modular design is one which incorporates multiple components or processes which are produced by different companies or departments. Innovating through the use of modular designs can facilitate rapid advancement. A monopoly can innovate by encouraging and incentivizing innovation in complementary, discrete modules, minimizing any negative impact, and ensuring continued integrity of the whole product or process. An example of modular design is software development that is divided into segments, with distinct actors working on independent segments. A specific example is the Linux operating system, with modules which continue to be developed open source by individuals [63].

Policy makers can also help advance societal priorities by providing protective spaces, or niches, for bolstering niche markets which are determined to be in the best interest of society. Protective spaces can serve to shield, nurture, and empower a new technology that would not thrive on its own. These protective spaces have boosted installed distributed generation in the electricity generation mix [39].

2.3 Summary

The diffusion of sustainable innovations and the speed of that diffusion are affected by a diverse set of factors, including economic, regulatory, psychological, organizational, and social. The adoption of sustainable innovations in the monopoly situation is of particular interest, as it correlates to the adoption of renewable distributed generation in the monopolistic electric utility market. Monopolies' incentive to innovate is directly correlated to the potential impact on their bottom line, whether the innovation be product or process. If a negative impact on their revenue stream is anticipated, the motivation to innovate will likely be externally driven by competition or regulation.

Diffusion of innovation in the electric utility market, which has historically been served by protected monopolies due to the societal benefits associated with stable electric supply, is changing as markets become deregulated. Studies indicate a short-term increase in R&D efficiency related to deregulation shown by a reduction in expenditures accompanied by increased patent activity, as competitors enter the marketplace. Innovators have the opportunity to enter the market via platform strategy, distribution channels, modularity and niche market creation.

3.0 Research Questions and Method

3.1 Research Questions

The successful and rapid adoption of sustainable innovations is critical in order to mitigate climate change. The most significant source of global greenhouse gas emissions is the production of electricity from fossil fuels [2]. Electricity production in the U.S. made up 35% of total CO_2 emissions in 2016, with 98% of total emissions derived from coal (68%) and natural gas (30%) [3]. Seventy-three percent of electric meters in the U.S. are owned and operated by IOUs, which were granted a monopoly in return for least-cost, reliable and stable electric supply [8]. IOUs therefore present a significant opportunity for facilitating the rapid adoption of distributed generation. There must be economic, regulatory, psychological, organizational, and social incentives to overcome barriers and turn them into opportunities in order for sustainable innovations to be adopted.

Electric utilities guaranteed a rate of return by regulators would theoretically not experience any impact on their bottom line whether they innovate or not. As Wang and Mogi showed in their study of Japanese electric market deregulation, there was no incentive for utilities to innovate in energy efficiency and renewable energy as the adoption of these would reduce profits [58]. Due to structural rigidity, monopolies do not innovate, especially when there is no competition [58-59].

An innovative product that competes with an existing offering could result in financial loss from the old technology, de-incentivizing innovation through the loss of extant profits, coined the “replacement effect” [50]. The monopoly continues to enjoy profits regardless of whether or not it innovates [51].

If the benefit for an innovation is high, there may be incentive for the monopoly to innovate. Yet if the benefit is unclear or low, then the costs of innovation and the failure rates of innovation may outweigh any incentive to innovate. Since innovation is risky, [53] and failure is an intrinsic part of innovation [56], natural rate-of-return monopolies without any competition do not exhibit an incentive to adopt sustainable innovations which could reduce their profits, opposite to Schumpeter’s theory that monopolies are effective innovators.

From the perspective of the natural monopoly, three of five reasons from LaMorte’s innovation diffusion factors are invalidated. A sustainable innovation may not offer the monopoly utility comparative advantages over the existing product. For the monopoly a sustainable innovation may not be compatible with existing cultural norms, and for the monopoly utility the new product does not have comparative benefits. However, cultural norms within the natural monopoly may differ from those of society, or a segment of customers. A sustainable innovation may offer consumers and society-at-large advantages over the existing product, for example less pollution.

Consumers may recognize other benefit to sustainable innovations that are not applicable within the monopoly. Companies are driven to change through consumer demand, yet with captive customers, monopolies have less incentive to appeal to consumer demand. As with other innovations, factors preventing them from adopting sustainable innovations include uncertainty and risk, and pressure from stakeholders [5].

> "All evidence suggests that most strategic innovations come from outsiders, rarely from established players" [42].

The first research question to investigate is:

1. Can natural monopolies be effective in promoting sustainable innovations?

If natural monopolies are not effective at promoting sustainable innovations, how can sustainable innovations be promoted in this market?

Since needs are already being met through existing products, diffusion of sustainable innovations requires transforming needs, as opposed to meeting them [20]. One way in which policy helps to instigate transformation by setting up protected spaces for niche technologies to thrive [39]. For renewable energy, these protected spaces frequently take the form of economic incentives or subsidies via feed-in-tariffs, rebates, and so on. Policy also sets up regulatory framework for allowing grid integration, component testing and accreditation. Innovations generating disruptions in monopolies are frequently caused by regulation, often leading to partial disruption and not a replacement of all technological competencies.

Distributed generation (DG) is not currently a replacement of all technological competencies held by electric utilities, which include generation, transmission and distribution. DG competes with the generation aspect, leading to partial disruption, but does not make the other generators obsolete since it is not dispatchable. Nor does DG currently render transmission and distribution obsolete. With coming advancements in energy storage, however, DG will become dispatchable and has the potential to compete with both generation and with distribution, potentially allowing customers to abandon the grid. If electric utility managers begin acting on the real risk that customers will defect as energy storage technologies continue to advance, they may get motivated to change.

An analogous transition in a monopoly satisfied with the status quo occurred to AT&T in the 20th century. Early on, the company grew as the U.S. government argued that all citizens should have phone service for national security reasons, and in 1918 began to regulate rates and competition. AT&T became a monopoly serving a significant swath of the market, and was considered by many throughout much of the 20th century to be a natural monopoly. AT&T was forced to change by several judicial decisions in the 1950s, 60s, and 80s that opened up the market, including an anti-trust ruling in 1982 that split the company [64].

Prior to the decision, not only did one have to purchase phone service through them, AT&T also required monthly rental of AT&T brand telephones in order to utilize their grid. After deregulation, the industry was forced to open up to allow other manufacturers of phones on their network. Following the decision, as opposed to renting phones for a monthly fee, consumers were now able to purchase their own phones and use them on the AT&T network, resulting in a major loss of revenue for AT&T, and eventually the closure of its phone manufacturing plants that were producing undesirable outdated designs [64]. Disruptive competition in phone service would not have occurred without the interference of policy.

AT&T continues to respond to changes hitting the telecommunications industry, as fewer consumers, only one in four, maintain landlines. Indeed, AT&T plans to dismantle all of its landlines by 2020 but this transition will depend upon policy since service providers are not allowed to discontinue service if a customer still wants the service. The most heavily impacted customers are those in poverty who can't afford wireless service, and those in rural areas who do not have viable alternatives. Similar to electric utilities, "landline phone companies have regulatory obligations in most states to supply lines at a reasonable cost to anyone who wants one. They also need federal approval to end service" [65]. A rapidly dwindling landline customer base spurred AT&T to advance legislation in 21 states over the past year, seeking needed regulatory permission to stop providing landline phone service. Designated as the "carrier of last resort by the FCC in 21 states" [66], the company is therefore obligated to continue providing service to all customers who request it, and at the lowest possible cost. Twenty states approved of the request by AT&T to stop providing landline service, with critics decrying the effort, advocating for those who continue to rely on landline service for communication and expressing concern than service that remains will be less reliable and more expensive.

> "The push from the telecom industry is forcing policymakers to re-examine what has long been a basic guarantee of government – that every American home should have access to a phone, along with other utilities such as water or electricity" [67].

The second research question therefore is:

2. For sustainable innovations that are potentially disruptive to diffuse in a natural monopoly market, does regulation play a critical role, as opposed to market forces?

As shown in the AT&T example, monopolies will be forced to change when regulations shift in the way to promote or favor the innovation that disrupts the monopoly company. Therefore, the next research question is: how can a monopoly company quickly adapt when such change happens, or how can a monopoly company proactively change before it is forced to do so?

Many incumbent firms have failed to react appropriately in the face of innovation. Christensen discusses the following reasons: companies follow their own value network that values only the mainstream market, companies fail to anticipate new technological innovations, and companies ignore new entrants [6]. However, in the regulated monopoly situation, the monopoly will still be the one most likely to win provided they conform their business with existing competence. There are various methods monopolies can deploy in order to drive innovations without taking risks themselves, for example the platform strategy which makes use of existing competencies, which in the case of electric utilities includes the transmission and distribution grid, and interfacing with customers [62].

Understanding a firm's core strengths is of critical importance when facing a disruption. While distributed generation adds electrons to the grid, it does not take the place of many existing core competencies in electric service delivery. As utilities move into the future electricity markets, it will be important to determine which core competencies will need to be sustained, and which should be overhauled or eliminated.

An example of the role of understanding and exploiting core competencies occurred during the disruption from analog to digital photography. Fujifilm and Kodak critically differed in how they viewed their respective core competences. Whereas Kodak identified brand and marketing as their core competence, Fujifilm regarded engineering skills and quality control as their core competences. These very different identities led to divergent strategies in dealing with the disruption they faced. Fujifilm successfully embraced the new digital technology, thriving through the disruption, while Kodak continued to try and hold onto their existing identification with analog. The two firms departed from similar revenue levels, employees and market share in 2001 to Fujifilm reaching 13 times the revenue of Kodak 15 years later as Fujifilm embraced the digital revolution. In 2016, Kodak employed 6,100 people to Fujifilm's 78,150, with $1.5b compared to $20.8b of revenue respectively [11]. Based on the case study of Fujifilm and Kodak during their transition during the digital disruption, this same study by Ho and Chen suggests that companies that are able to transform the organization to adapt to new business conditions created by the disruptive innovation while maintaining organizational continuity have a better chance to survive and thrive during and after the disruption of innovations [12].

An example of not adapting and conforming to evolving consumer expectations, and failing to continue to innovate, is the aforementioned AT&T phone manufacturing that relied on exclusivity of the marketplace, rather than innovation. As soon as competitors were allowed access to the market, AT&T completely lost its market share and had to close telephone manufacturing plants. By the time they considered reacting, it was too late [64].

> "Long-term market leaders focus intently on future emerging mass markets. They innovate relentlessly to cater to that emerging market (e.g., Procter & Gamble) and are paranoid about competitors getting there first (e.g., Intel, Microsoft). Most importantly, they are willing to cannibalize their current assets to realize that future potential (e.g., Gillette in the wet shaving market or Procter & Gamble in detergents). In contrast, dominant incumbents that succumb to technological change are content with past successes, are disdainful of new entrants, focus on current products or current customers, and are highly unwilling to cannibalize current assets and products to build future markets (e.g., Xerox in the 1970s and 1980s)" [68].

The third research question therefore is:

3. Is a monopoly incumbent firm that is able to adapt and conform its business to strategically and actively incorporate a sustainable innovation into its existing competence less likely to be disrupted by such innovation?

As history sees many examples of companies that failed to incorporate innovations which later disrupted the business, one important question to ask next is: What enables a monopoly incumbent firm to actively change to incorporate the sustainable innovation?

In order to establish success, it is critical to determine how leaders of incumbent firms deal with change. What is their internal organizational culture, and do they ceaselessly innovate [68]? In order to be successful at deploying sustainable innovations, a company must be unique in many aspects, including culture, leadership, business practice, partnerships, and client emphasis [21]. Culture cultivated within a company allows it to adapt to a changing world, reward and motivate employees, promote diversity, and create new opportunities in future markets, among other aspects. Effective leadership through the market transition is critical to a firm's success [69].

Deregulation of the electric grid facilitates the use of the grid platform for wheeling solar electricity by IPPs. Increased social support for and understanding of solar energy also improves the diffusion of this innovation. Sustainable innovations that require broader cultural change take much longer to diffuse or may not achieve diffusion [20]. If the product being delivered serves the same function as the incumbent product, for example, electricity, and the innovation is effectively invisible to society, it requires no cultural change. The cultural change that is required for such sustainable innovations is within the monopoly incumbent. The primary barrier identified for the adoption of sustainable innovations inside a company is that it would require a change in the corporate mindset [22].

One of the challenges for monopolies is in adopting new strategies for conducting business [70]. Not only are incumbents faced with the challenge of learning from innovations in the deregulated marketplace, they must also unlearn strategies which relied on the former dominant paradigm [88-90]. This type of transition requires leadership able to guide an organization through this rebirth [69].

Yet a leader with a vision alone is not enough. The effective leader needs to sell their vision to staff as well as the Board, which is especially true in the U.S., with the existing financial system's focus on short-term gains. In the case of Kodak, shareholder pressure for short-term gains combined with high executive compensation contributed to the inability to diversify and subsequent lack of development in the digital market, when ironically Kodak actually invented the first digital camera. Fujifilm on the other hand, profited from the long-term culture within the company itself as well as the culture of Japanese society, which facilitated the successful pursuit of the leader's vision for the future of the company outside of short-term interests [11].

At AT&T in the mid-1900s, the company built commitment and motivation in its employees, rewarding them with guaranteed employment for life. The obedience and conformity AT&T required in return squashed creativity, change and diversity. Until 1973, when AT&T settled a massive affirmative action settlement, zero women had been recruited into the company's management training program, and few people of color. Personality tests were required for executive men, demonstrating psychological suitability, in order to advance. AT&T was predictable, regimented, and took too long to deliver new technologies to market. They did not have an environment that encouraged innovation, and were completely stunned by the disruption of the 1982 antitrust decision resulting in a breakup, pressed forward by competing marketplace advances and public impatience with the lethargy at AT&T [71].

> "The big challenge for established companies is organizational: they need to develop the culture, mind-set, and underlying environment to continually question current success while promoting continual experimentation" [42].

The fourth research question therefore is:

4. Does the right environment/culture enable the strategic change needed for a monopoly incumbent firm to adopt sustainable innovations that are potentially disruptive?

Besides the right environment and culture needed for a monopoly incumbent firm to enable the strategic change, recognizing the need to change is also critical.

Established companies fail when they ignore new entrants, and when they stay too close to existing customers [6]. The market size for an innovation initially is often small, so a firm has an opportunity to quickly recognize and respond to any core sales reductions. Understanding existing competences, recognizing whether they can or should be sustained and having the courage to act on it, all while exploiting opportunities to diversify will help a firm respond to innovation. Fujifilm correctly anticipated the digital disruption and proactively exploited new business opportunities, while Kodak sat on its heels, waiting for analog to return [11].

Sustainable innovations will be adopted at a greater rate with loose linkage between elements [20]. From the customer perspective, there is a loose linkage between elements when considering adding a renewable energy system because it does not impact electricity availability or lifestyle. The linkage is tight, however, from the perspective of the utility, as the uptake of renewable energy disrupts the existing practice of electricity generation and distribution as a whole. Monopolies are more likely to adopt incremental innovations [58]. It follows that diffusion of renewable energy at the utility will be lethargic.

As established earlier, in order for an innovation to be adopted, it must have observable benefits over the incumbent product [19]. A natural monopoly may struggle to derive any potential benefits arising from a product perceived to be competitive. Outside of direct revenue impacts, the utility has an opportunity to exploit benefits of adopting renewable energy, which could include enhanced reputation and brand value as demonstrated by Keeble et al [21].

Marketing value of adopting sustainable innovations is exploited by firms in the open market. The adoption of sustainable innovations serve to enhance reputation and brand value [21]. Indeed, corporations from Budweiser to Macy's are advertising their use of renewable energy to power their operations, recognizing consumer demand for increased corporate responsibility in the face of climate change and other challenges. According to the Solar Energy Industries Association, U.S. corporations are installing solar energy at their facilities all over the United States, with Target at the top of the list with the most solar energy installed in 2017, Walmart at second place, and others in the "Top 10 Corporate solar users" list including Costco, IKEA, Amazon, and Apple [72].

Long Island Power Authority is a State of New York publicly-owned transmission and distribution utility. Stemming from the poor response after Hurricane Sandy, LIPA underwent a transformation. One of LIPA's first goals was to understand what their customer's needs were. Through surveys, they found that their customers valued reliable electric service above all else. In response, LIPA has been investing in grid reliability measures such as storm preparedness and grid reliability [73]. In terms of renewables, LIPA presents their commitment to deployment as being driven by compliance with the State of New York's Clean Energy Standard, enabling customers with choices, and reducing peak energy use [73].

The Long Island Power Authority (LIPA) is embracing the use of solar energy by incorporating it into its strategy to deliver reliable electricity to its customer base, as this base grows. In small towns where population growth is predictably driving an increase in electricity consumption, but where the distribution grid was not built to support it, LIPA is paying developers to install distributed generation systems. LIPA estimates that constructing additional power generation capacity locally, right where it is consumed, will save the company more than $80 million dollars in grid expansion [74].

> "It's actually cost-effective to add renewables." *LIPA VP of Environmental Affairs, Michael Deering*

The fifth research question therefore is:

5. Is a monopoly incumbent able to recognize and pursue new market opportunities arising out of a sustainable innovation instead of viewing it as disruptive more likely to contribute to the successful diffusion of such innovation?

3.2 Research Method

This thesis intends to examine the role of rate-of-return regulated electric utility monopolies in the adoption of renewable energy innovations, and posits five research questions related above. Analysis based on literature and available data has been performed and the research questions were developed from the literature and tested using a case study to contextually relate concepts. Data was gathered from a variety of secondary sources including industry publications, reports, government publications, and peer-reviewed academic studies. Industry sources included Solar Energy Industries Association website and the associated publications, *Fortune* Magazine, *Power* Magazine, and the GreenTech Media website and its publications. Reports included the Arthur D. Little Innovation High Ground Report. Government sources included the U.S. Department of Energy, the U.S. Energy Information Administration, the National Renewable Energy Laboratory, and the Vermont Public Utilities Commission. Sources for academic studies included eight from *Energy Policy*, five from the *Journal of Cleaner Production*, two from the *Journal of Organizational Change Management*, two from *Organization and Environment*, two from *Technological Forecasting and Social Change*, and one from *Energy Policy*.

To answer the research questions, the US utility industry is targeted in the case study. One case study was selected in this nascent industry as an example of success, so it is not necessarily representative for industries in other locales or in other situations. Distributed generation (DG) is a sustainable innovation transforming the electricity system. Solar photovoltaics (PV) in particular has the potential to create long-term impacts due to its flexible scalability compared to other DG including solar thermal, wind or hydropower. While it remains a site-specific resource as are the other DG technologies, PV is widely deployable (38.6% of our total annual generation needs can be met through rooftop solar [75]), and the same essential components are used in both utility-scale and residential applications so PV installations can succeed at many scales and in many locales. Associated supply and demand cost reductions also contribute to this scalable deployment by means of utilizing the same essential components. Oftentimes the most cost effective DG to deploy is PV.

3.2.1 Background – The electricity industry in the United States

In the beginning of the 20th century, states started regulating the nascent electricity industry through the establishment of Public Utilities Commissions (PUCs). Companies were provided exclusive rights to operate within a given territory in exchange for being regulated [76]. Customers who lived in a given utility service territory had no agency in choosing which utility to purchase power from, but PUCs regulated these electric monopolies by determining the profit level for the companies, and also the price that the captive customers would have to pay for their services. This system worked well until prices started rising due to the energy crisis and increasing environmental regulations in the 1970s [76].

In response, Congress passed the National Energy Act in 1978, significantly consisting of the Public Utility Regulatory Policies Act (PURPA). PURPA facilitated the partial deregulation of the wholesale electric market by requiring utilities to interconnect with nonutility facilities that were registered with the Federal Energy Regulatory Commission (FERC) and generating power [76]. PURPA is often the mechanism by which renewable energy is added to the grid by IPPs [77].

Additional regulations impact the diffusion of renewables in the local grids. At the State level, net metering rules incentivize or discourage renewable energy deployment in the United States. The State can require or encourage generating utilities to incorporate a certain percentage of renewables into their grid, sometimes even specifying the portion of solar and wind required within a certain timeframe through their renewable portfolio standards (RPS). The adoption of State-level RPS swept many states throughout the 1990s and into the 2000s. These standards are often voluntary, and aim to variously reduce dependence on fossil fuels, reduce carbon emissions, and increase renewable energy deployments oftentimes by specifying a percentage of electricity generation which must come from renewables within a given timeframe [78]. Ownership issues can also be specified in law, for example third-party ownership, leasing agreements, conversion of farmland, and so on [79].

Electric utilities in the U.S. are often distinguished by whether they are generation and transmission (G&T), and/or distribution. Many utilities own the means of generation as well as service end-consumers with both transmission and distribution. The majority of utilities are municipal utilities (62%), yet they serve only 10% of the population. The remaining utilities are publicly owned or cooperatively owned. Most small utilities are distribution utilities, with many owning small peaking plants used only when requested by the independent system operator (ISO) or regional transmission organization (RTO). Like other monopolies, electric utilities control the distribution channel and the platform [8].

About one-third of electric utilities in the United States, less than 1,000 utilities, actually produce power, while the remaining two-thirds simply resell and distribute that power [81]. Owning the means of generation and distribution means that utilities play a major role in the adoption and integration of renewable energy into the electricity distribution system. Figure 3 below shows the breakdown of utility organizational structure versus percent of population served. As evidenced by Figure 2, IOUs are the dominant design of electric utilities in the U.S. since they serve 73% of the public [8]. Other electric utilities are organized as cooperatives, municipally owned, and publicly owned. Since IOUs control the majority of electricity supply in the United States and as a result often face different regulations than non-IOUs [8], they are in a unique position to control the speed at which distributed generation diffuses, and thus the primary focus of this research is on IOUs. A natural monopoly creates high barriers to entry that limit or prevent competition. Very high infrastructure costs related to the investment in power plants and transmission and distribution lines make electric utilities natural monopolies. [80]

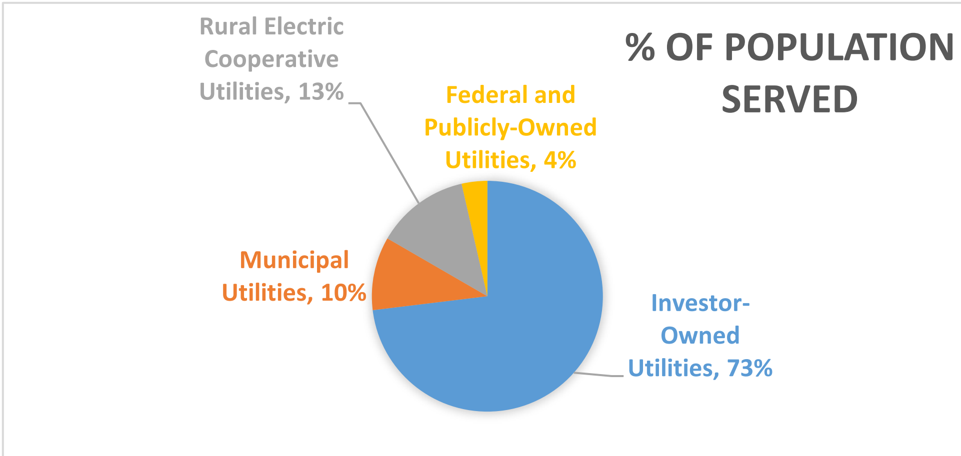

Figure 2: Utility Structure vs. Percent of Population Served [8]

3.2.2 Background – Growth of Solar Energy in the United States

As demonstrated in Figure 3, the vast majority of electricity generation in the United States remains fossil-fuel and nuclear-based [82] [8]. Figure 4 illustrates the breakdown of renewables on the grid, with the majority comprised of hydropower and wind [82]. Since deregulation of the electricity wholesale markets occurred in the late 1970s, innovating IPPs have been making use of the grid platform and entering the formerly monopoly-dominated wholesale electricity market. Growth in IPPs started in the 1980s and was initially driven by traditional fossil fuel energy sources. As the price of wind and solar dramatically decreased, some IPPs expanded by investing in utility-scale renewable power plants, and wheeling renewable power over the existing grid platform, attracted by relatively low operations and maintenance costs, as well as zero ongoing fuel supply costs. Currently 40% of the U.S. electricity generation market is held by IPPs [9]. IPPs have provided 80% of the total investment made in installing renewable power plants [83].

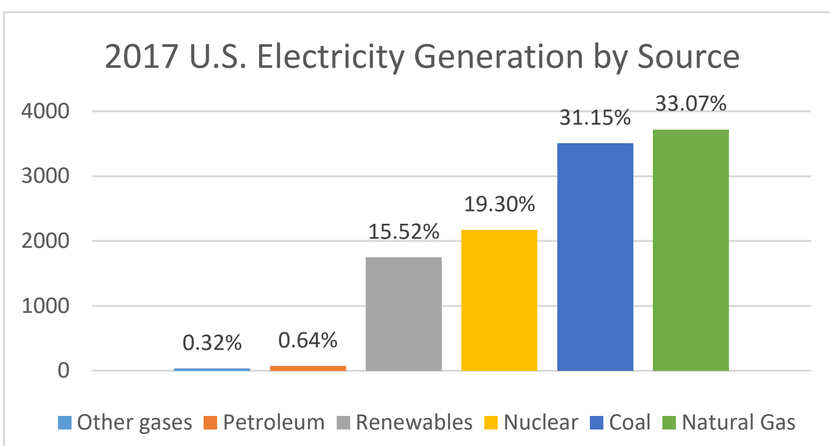

Figure 3: Natural Gas, Coal, and Nuclear comprise 84% of total U.S. electricity generation [101]

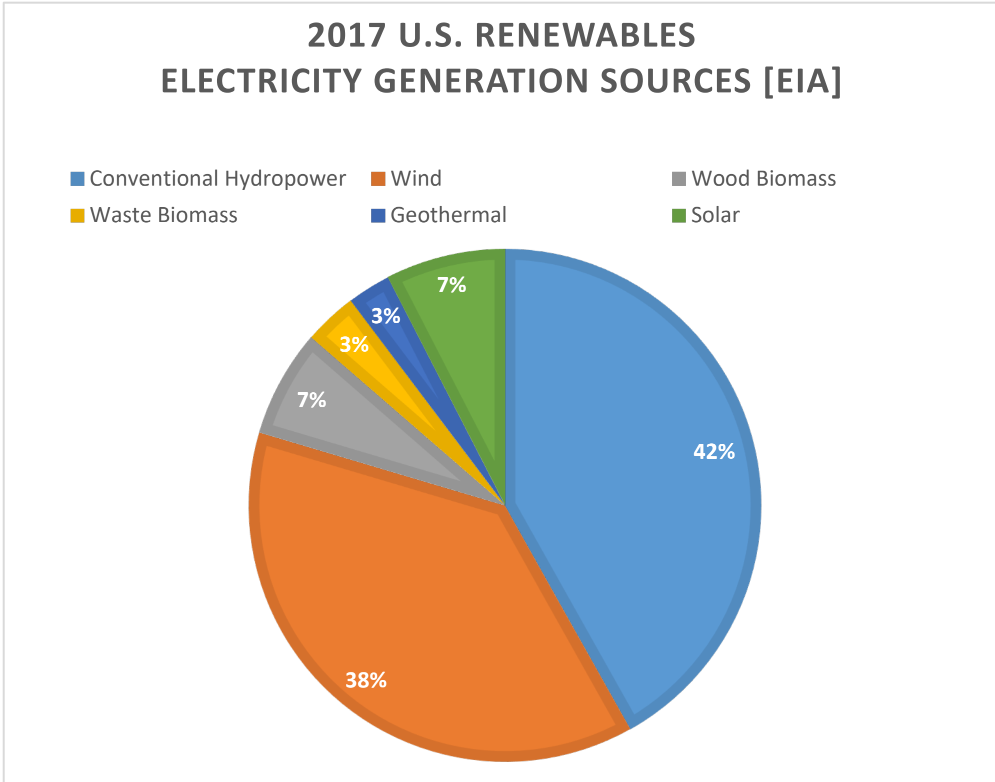

Figure 4: Hydropower and wind comprise the greatest proportion of renewables on the U.S. electricity grid [101]

Despite barriers to the diffusion of renewables into the existing electric grid, its overall incorporation increased by 7.82% between 2001 and 2017 accounting for a total increase of 958.5 thousand MWh per day, as demonstrated by Figures 5 and 6. Over the last 17 years, the proportion of renewables on the U.S. electric grid has doubled, and solar energy has significantly increased. Hydropower and wind dwarf solar energy in the renewables category. Solar energy comprises a very small proportion of the total renewable portion of grid generation. Conventional hydropower (41.86%) and wind (37.73%) comprise the vast majority of renewable electricity generation, making up 79.59% of total renewable generation in 2017 [82]. By 2020, solar energy is projected to only make up 3% of the grid's capacity [84]. Between 2012 and 2017, solar power expanded rapidly to make up 7.5% of total renewable generation in 2017 [82].

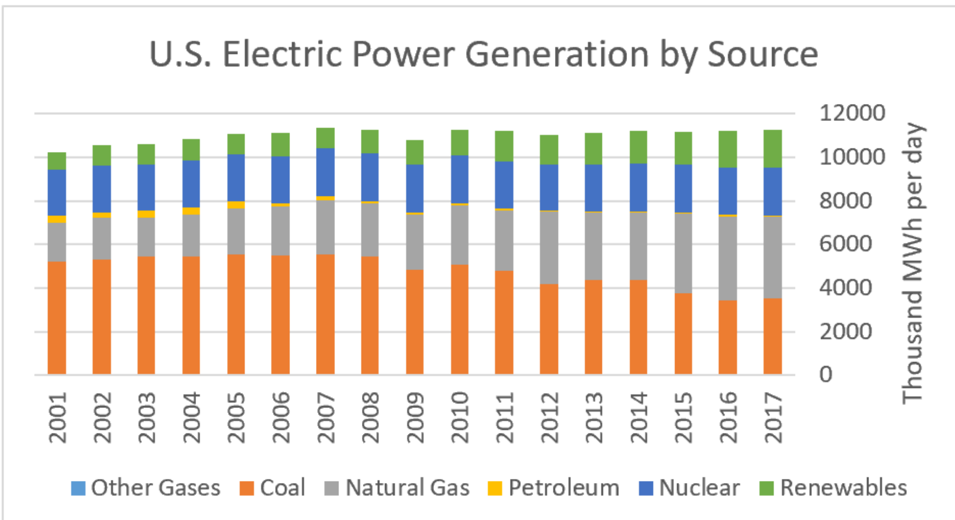

Figure 5: U.S. Renewables and Natural Gas proportion of electricity generation increasing [8]

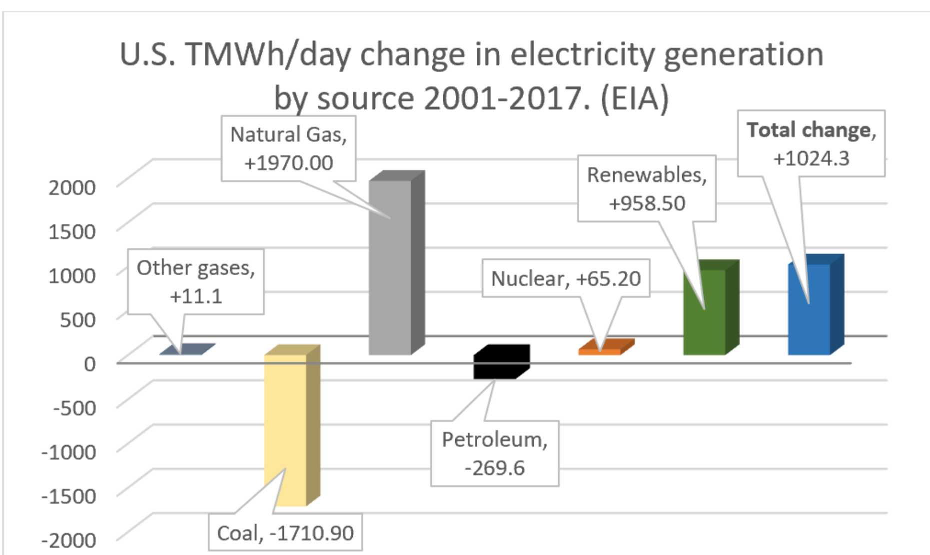

Figure 6: Change by TMWh per day in electricity generation by source 2001-2017 [101]

Natural gas increased in the electricity generation mix by 15.95%, accounting for a total increase of 1,970 thousand MWh per day. During the same time period, electricity power generation itself increased by 1,024.3 thousand MWh per day. So, the increase of renewable integration into the grid did not even accommodate the total increase in electricity generation driven by increased consumption [82]. The increase in natural gas electricity generation over the past 17 years essentially matched the reduction in coal generation, while renewable electricity generation added to the grid almost matched the total increase in electricity consumption nationwide.

As shown in Figure 7 below, increases in renewable electricity generation have primarily come from solar and wind *[82]*.

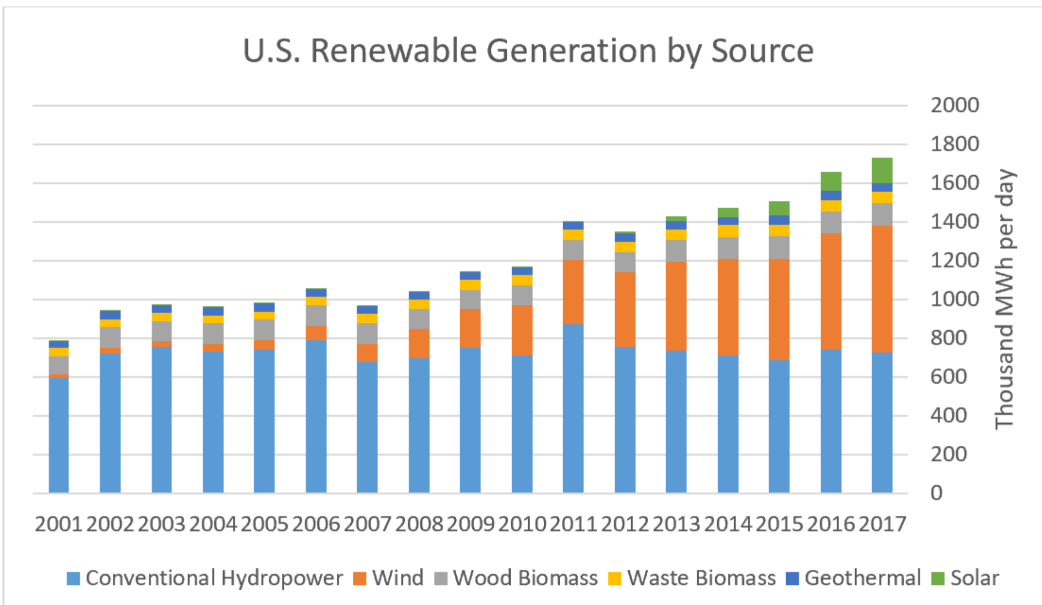

Figure 7: Within renewables, solar and wind account for most of the overall increase [101]

Whether it is a G&T electric utility, and/or a distribution utility, one way in which utilities incorporate renewables is through distributed generation on their grid. End-users install renewable energy systems on their properties, and power their operations when the system is generating energy, put energy back onto the grid, or both at various times. Installations, depending on size, are sometimes incentivized by the utility in order to meet policy goals. Utilities also sometimes invest in their own renewable energy generating assets, wind farms or solar farms [8]. When utilities purchase power from the wholesale market, they may be purchasing renewable energy since it is often the cheapest electricity [85]. Since there are fuel input and shut-down costs associated with fossil fuel power plants but not with renewables, they are often cheapest and will bid into the grid at any price [85].

Solar energy follows the S-curve (magnitude of product's performance improvement differs as technologies mature), and incumbents' response to substitution (old technology continued to be improved after new technology introduced, incumbent firms emphasize new technology shortcomings). In order to continue to thrive in the face of the change occurring in their industry, incumbent electric utilities must consider how best to react and take an active role in identifying technological competencies to thrive in the future. With this issue being nascent, there are not a lot of existing examples to follow, or longitudinal studies that help determine which course of action is the best to pursue in order to achieve the goals of stable electric service, offered at the lowest possible cost, while protecting the environment.

Factors affecting the diffusion of solar energy are very similar to those impacting the diffusion of other sustainable innovations. Those categories are reflected in Section 2.1, Table 1, and include economic, institutional/regulatory, behavioral/psychological, organizational, and consumers/market. For example, policy can facilitate or prevent the incorporation of distributed generation into the electricity generation mix through common mechanisms like net metering. Depending on the structure of net metering policy, it can either improve the financial payback and incentivize investment by compensating generators at the retail rate, or disincentivize investment by compensating generators at the wholesale rate. Support from society can increase adoption and thereby drive down cost, and more research and development can overcome technical issues such as the lack of 24/7 availability. According to the National Renewable Energy Laboratory, generating 80% of our nation's power supply from renewable energy by 2050 is technically feasible. In order to facilitate that shift, however, "both technological and institutional" innovation will be required, with both policy and social changes accompanying technological advancements [86]. Innovations are often slowly adopted over time, and this is no different for changes in electricity generation. However, the causes for relatively slow adoption of RE are particularly important to recognize when confronted with the rapid pace of climate change. Understanding and identifying specific barriers associated with the adoption of RE, and specifically solar energy, into the U.S. electric grid, will facilitate the design of appropriate solutions for overcoming these barriers [5].

3.2.3 Research Method –the selection of case

Evaluation of the research questions presented earlier in section 3 is conducted by a case study of an IOU that is a leader in innovation. Incumbent utilities throughout the United States have been slowly moving to adopt solar energy on their grids as demonstrated by the low percentage of penetration nationwide, but one IOU in particular stands out in striving to change along with the marketplace, Green Mountain Power (GMP) in Vermont. The generation mix of solar energy on the GMP grid is 30 times the national average [87] [82]. GMP is innovating, and provides energy to customers that is greater than 60% renewable, with a mix of wind, solar, and hydro both self-generated and purchased from other sources. GMP is further promoting customer-sited distributed generation, including solar with energy storage [88]. Their unique ability to change along with the market provides one interesting demonstration of a monopoly successfully incorporating sustainable innovations. Understanding how GMP has accomplished this is important to informing replication elsewhere.

GMP is both a monopoly utility and an innovator. In order to find information on this company, which does not have a long history of incorporating renewable energy onto their grid, research was acquired in a variety of ways. Research media about the company included popular media articles, documents submitted to governmental regulatory bodies, and websites. Research media regarding electricity generation included data collected and generated by governmental entities. Scholarly articles on innovation adoption for monopolies as well as sustainable innovation adoption were studied. Data found showed detailed information regarding impacts of diffusion in the State of Vermont as well as the level of diffusion.

4.0 Case Study

In this section, the increase of solar on the distribution grid in Vermont and the adoption of PV by the IOU GMP is investigated in order to evaluate the research questions posited in section 3.1.

4.1 Background: Green Mountain Power and Vermont Electric Power Company

Vermont's electricity sector is represented by more than 20 utilities boasting the lowest wholesale electricity costs in New England, meanwhile touting an advanced transmission grid with the lowest carbon footprint in the country. By virtue in part of the decommissioning of a nuclear power plant on which the state was heavily reliant (73.7%), Vermont is transitioning away from nuclear power [89]. Electricity generation within the boundaries of the State is heavily reliant on multiple hydroelectric facilities. The State also imports a significant amount of its electricity. The amount of solar energy on the Vermont grid was insignificant until around 2009-2010, when the installed capacity starting increasing rapidly. Contributing factors to the increase include policy (renewable energy Standards, net metering requirements, incentives to adopt, etc.), and installed cost.

Well known for its culture of independence and self-reliance, part of the rationale for promoting the transition of Vermont's energy system was to make the grid more robust with greater distributed production. Almost 20 years ago Vermont policymakers set about encouraging growth in the nascent solar energy market through the introduction of a robust net metering program combined with incentives. These policies led to considerable growth in the installed capacity of renewables in GMP, the state's largest utility, by 1,300% since 2013 in GMP. According to GMP, solar now accounts for almost 30% of all distributed capacity on their grid, "ranking Vermont second only to Hawaii." This figure contrasts sharply to the Northeast ISO which includes Vermont, and has a solar penetration of only 8.4% of peak overall [87]. The increase in solar on the Vermont grid, along with the other sources in the energy generation mix, can be visualized in the Figure 8 below. Note that unlike other states in the Northeast, Vermont includes Canadian hydropower in its renewable portfolio [90].

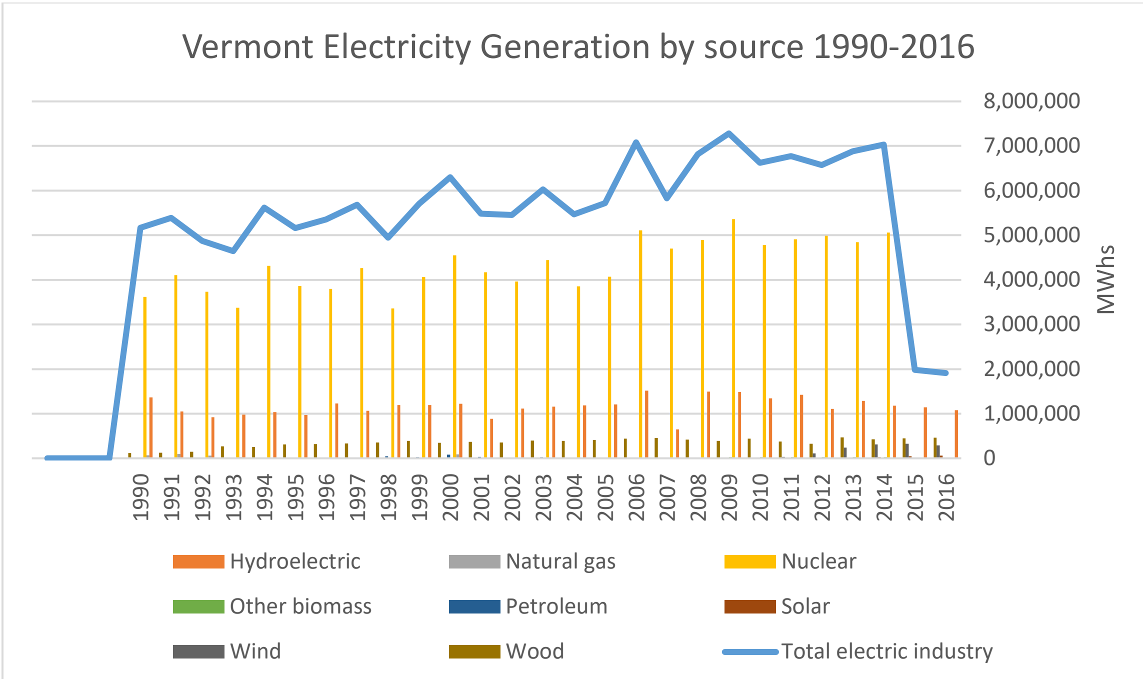

Figure 8: Vermont Electricity Generation by Source [109]

The Vermont legislature passed enabling legislation coined SPEED (Sustainably Priced Energy Development), which increased the development of solar energy in state in part because it allowed the sale of renewable energy certificates (RECs) out of state. In 2014, Vermont's electric utilities were earning about $50 million annually through the sales of RECs [90]. That same year, Connecticut prohibited the purchase of RECs from Vermont, alleging that the renewable attributes were being sold, while the renewable attributes also counted towards the State's goals of meeting their RPS [90].

Figure 9 demonstrates the expansion in installed PV capacity in Vermont, compared to the cost per Watt. Throughout this entire time period, the cost per watt of installed solar energy systems decreased sharply, from over $8/W in 2009 down to around $3.50/W in 2017.

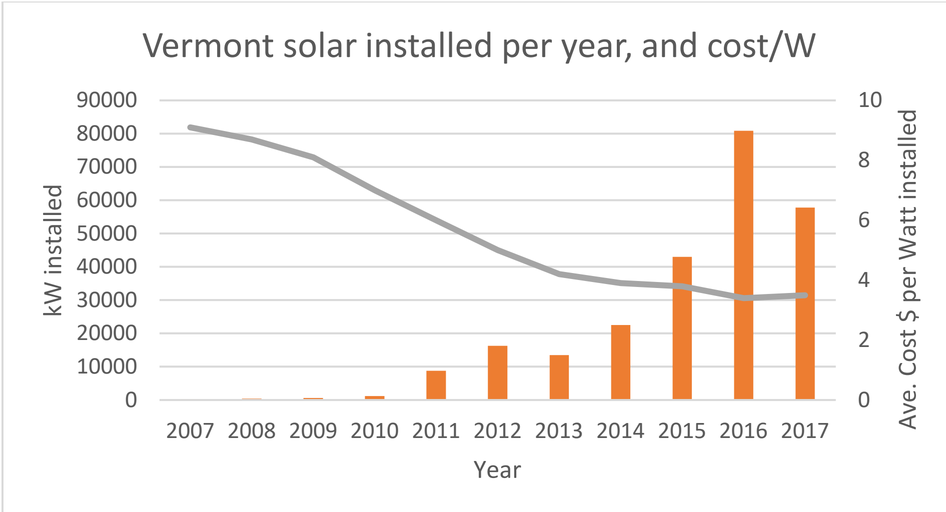

Figure 9: Vermont installed solar, compared to Cost per Watt [91-93]

4.2 Research Question Evaluation

The economics of adopting solar energy have improved significantly over the past decade as installed costs fell dramatically. This has occurred due to technology advancements, a decrease in equipment and installation costs as competition grew and supplies became widely available, financial incentives, and improvements in installation techniques.

The case study of GMP was examined to evaluate the validity of the research question posited in section 3. Evidence is provided below.

Research Question 1

1. Can natural monopolies be effective in promoting sustainable innovations?

Studies argue that the reasons to the slow renewable energy adoption worldwide are either the absence of suitable policies or the absence of finance mechanisms [83]. The success of policies depends on the marketplace design. According to Nesta et al. in 2014, competitive marketplaces are more conducive for enacting successful renewable energy policies [91]. A study by Carley concluded that competitive electricity markets in deregulated states encourage development of renewable energy, since they demonstrate greater rates of renewable energy deployment, albeit lower percentages of renewably generated electricity [78].

Solar electricity is a sustainable innovation that has been experiencing rapid growth over the last decade. Still, framed in terms of Rogers' bell curve, the U.S. is nationally at the innovator stage [16], as it comprised merely 1.16% of the total electric grid generation mix in 2017 [82]. Incorporation of solar into the electricity generation mix varies significantly state to state, with a few states in the Early Adopter to Early Majority phase [16], for example in 2017 comprising 16%

of California's electric grid, 11% of Hawaii's, 6% of Arizona's. Nationwide, there is a negligible amount of solar generation in thirty-eight states, accounting for less than 1% of the generation mix. While many of these states have an RPS for increasing solar penetration on their grids, penetration is increasing slowly in a majority of states and significant growth is focused in a few [92] [93].

Growth in the solar industry has been significantly driven by IPPs, which own the vast majority of all renewable energy generation currently on the U.S. electric grid, providing the estimated 80% of total funds required to do so, despite many of the IPPs having a history in the fossil fuel industry [83]. Growth of IPP-owned renewable energy in a given utility service territory is more likely to be motivated by available incentives or requirements driven by policy, which would facilitate IPP asset ownership, as opposed to promotion by the utility monopoly.

While PURPA paved the way for IPP roll-out of distributed generation, requiring the transmission and distribution operators to allow the wheeling of energy over their grid, utilities often put obstacles in the path of IPPs, making it difficult or impossible to actually realize proposed projects. Obstacles may kill projects. Large-scale projects can be met with lengthy interconnection schedules or unusual utility requirements. Utilities deploy tactics like increasing costs for solar energy systems by charging more for electricity used during peak hours, not allowing certain bill charges to be bypassed, adding a monthly fee for providing access to the grid, and increasing fixed monthly charges. Utilities also lobby for rules through the PUC or elsewhere that favor their continued incumbent status and limit competition [112-113].

When customers want to interconnect their solar energy system to GMP's grid, GMP typically retains the associated RECs. For several years, GMP was improving its bottom line while diffusing sustainable innovations, when it realized a significant return by reselling RECs generated by solar being added to its grid by third parties. In 2014, Vermont's electric utilities were earning about $50 million annually through the sales of RECs [90].

Based on customer feedback, GMP initially spoke to the State Legislature in favor of the effort to grow renewable energy development, pioneering a solar adder to further incentivize solar, due to the value they perceived it held in reducing peak daytime loads, and the value it brought with RECs which could be resold. In 2018 however, GMP in their biennial update of the net metering program comments to the PUC, recommended that the incentives be reduced to prevent costs from climbing and because of the limited additional value that increased capacity delivers [87].

The report to the PUC indicates that significant solar deployment in the State has successfully achieved target goals of "providing clean energy to Vermonters while offsetting traditional power supply costs such as peak demand costs" [87]. However, it also suggests that additional solar energy deployments will not continue to realize the same benefits of existing systems, since the desired peak reduction has already been maximized. Specifically, GMP's concerns are focused on larger net metered systems between 150kW and 500kW, as those are generally not directly offsetting a customer's usage, but rather fed directly to the grid [87]. Further, although this was not mentioned in their report to the PUC, due to new regulations barring the resale of RECs to prevent double counting associated benefits, GMP no longer resells RECs out of state as they initially did [94].

In Vermont's GMP service territory, solar now accounts for almost 30% of all distributed capacity on their grid. This figure contrasts sharply to the Northeast ISO which includes Vermont, and has a solar penetration of only 8.4% of peak overall [87]. Regarding research question 1, given the right circumstances, natural monopolies *can* be effective organizations to promote sustainable innovations. Those conditions include regulation and financial incentives.

Research Question 2

2. For sustainable innovations that are potentially disruptive to diffuse in a natural monopoly market, does regulation play a critical role, as opposed to market forces?

U.S. federal incentives for adopting renewable energy first appeared on the landscape in 1978 [95]. Currently, federal incentives are in the form of tax credits, depreciation, and various grants and loans available through federal agencies. Tax credits are an exclusive potential benefit, as they require a taxable income in order to take advantage of them, ensuring that the bulk of the financial benefit goes to wealthy individuals and large corporate entities. In the U.S., this sort of policy favoritism is leading to a market controlled by a few solar power companies, significantly outpacing locally-owned projects [95].

Subsidies impact all generation markets including fossil fuels which also receive subsidies in the United States. Subsidies keep the prices artificially low for electricity produced by fossil fuels. The Trump administration recently announced plans to bail out struggling coal and nuclear facilities which would add to the already significant subsidies in place [96]. Fossil fuel subsidies in the United States amount to over half a trillion dollars annually [83] [97].

With reliability of electric supply of paramount importance to society, a truly deregulated marketplace seems out of the question as any hiccup in supply leads to voter demand for regulatory interference. Policy makers are left with the unenviable task of attempting to regulate appropriately to ensure that utilities simultaneously achieve the impossible: 1. Ensure stable supply at 2. a low cost, while 3. protecting the environment [98].

Political interests today play an integral role in guiding electricity production, transmission, and consumption [83]. Almost 20 years ago Vermont policymakers set about encouraging growth in the nascent solar energy market through the introduction of a robust net metering program combined with incentives. These policies led to robust growth in renewables--a 1,300% increase in GMP territory alone [87]. While GMP touts being customer-driven, it is unclear as to whether the other factors associated with the diffusion of sustainable innovation would have provided adequate incentive for such a significant increase in distributed generation on the grid there.

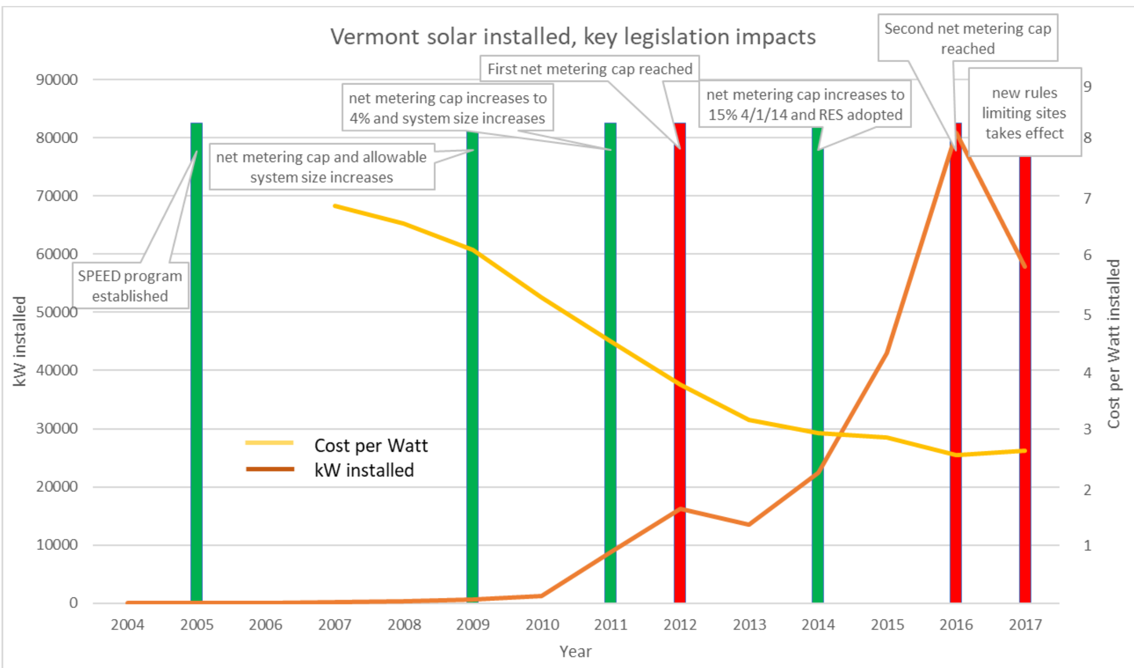

Figure 100: Key legislation impacts on Vermont installed solar, compared to the installed Cost per Watt [91-93] [102-107]

The increase in diffusion of PV in Vermont appears to be directly correlated to regulations passed, as shown in Figure 11, where the green and red bars indicate years that legislation took effect. The Vermont legislature first established the Sustainably Priced Energy Enterprise Development (SPEED) program in 2005 to encourage deployment of renewables [99]. When the feed-in tariff, net metering cap and allowable system size increases passed through the legislature in May 2009 and took effect September 30 of the same year [100], there was a noticeable increase in installed capacity through 2012 [101], when the first net metering cap was reached [102]. The net metering cap was increased again in 2014 [103], and the installed capacity increased dramatically again until 2016, when the second net metering cap was reached by most utilities [104]. In 2017, new rules limiting ground-mount solar sites, encouraging roof-mount systems, and reducing net metering compensation took effect, with the explicit purpose of reducing the expansion of the net metering program [105]. Note that the timeline versus installed capacity [101] may differ from a timeline versus permitted projects, as permitted projects will be grandfathered in but may not be installed until the following year [105].

The figure clearly shows that cost per Watt was also decreasing at the same time [101] [106], so both factors appear to have had a significant impact. But each time a policy limit was met, the installed capacity notably decreased. It is unclear whether or not the same level of diffusion would have occurred there without regulation. However, the adoption levels in surrounding states without the same regulatory environment offer a clue: in GMP service territory, solar now accounts for almost 30% of all distributed capacity on their grid [107] [87]. The Northeast ISO serves Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont [108], and its solar penetration is only 8.4% of peak overall [87].

Research Question 3

3. Is a monopoly incumbent firm that is able to adapt and conform its business to strategically and actively incorporate a sustainable innovation into its existing competence less likely to be disrupted by such innovation?

One of the reasons that utility companies are frequently cited for preventing the integration of renewable generation on to the grid is technological limitations and intermittent electricity supply due to the inability of traditional power generators to react to weather changes impacting fluctuations in distributed generation. With intermittent renewable power, stable forecasts of predictable power have been difficult, creating challenges in keeping consistent supply when renewables are unavailable.

Vermont Electric Power Company (VELCO) is a transmission utility owned by the state's distribution utilities, including GMP [89]. The GMP team understood that evolution had to occur in order to successfully integrate and maximize the amount of renewable energy on the grid. So they developed a strategic alliance with IBM, the University of Vermont, and VELCO, and invested in key infrastructure. This partnership led to a groundbreaking weather forecasting platform that facilitates grid management. This system accurately forecasts weather in Vermont down to 1 square kilometer, facilitating grid management by predicting available solar and wind resources with 90+ percent accuracy. In turn, this allows VELCO to reduce reserve power consumption and better manage the integration of renewables [10]. And the benefits of this system are not limited to renewables grid integration--it further facilitates weather event preparation and response [109]. This innovative tool maximizes renewables while facilitating consistent delivery of energy to the end-user.

This partnership resulted in a new company. None of the partners kept the new firm in-house, thereby allowing innovations and development to occur in the focused and reasonably unfettered environment. This proactive response to sustainable innovation allowed VELCO to adapt and incorporate it successfully [10] [109]. Tom Dunn, VELCO CEO, stated that:

> “Having traveled around the country, in my judgment what we are doing here is some of the most innovative work in the nation. … Once again Vermont demonstrates its collaborative ability to serve as an energy innovation workbench – this time by closely linking grid management, enhanced predictive weather capabilities and renewable energy to provide better value to our customers and Vermont.” [109]

GMP is actively working to avoid the “utility death spiral”. The theory of the “utility death spiral” assumes that as customers deploy more energy efficient technologies and produce their own renewable energy onsite, they consume less utility power thereby reducing utility revenue. This in turn leads to higher utility electricity rates, further driving customer defection. [110] [111] [112] [113] Note that while local energy efficiency and renewable energy measures occur, on net the U.S. continues to consume an increasing amount of electricity [82]. As aforementioned, the amount of renewables added to the grid since 2001 is less than the increased demand for electricity. Data demonstrates that electricity consumption continues to grow on a nationwide basis, albeit perhaps not at the rate the utilities predicted.

Making up for a reduction in per capita electricity consumption through increased energy efficiency and distributed generation deployment, GMP is helping customers convert from fuel oil furnaces to electric heat pumps, and incentivizing the use hot water heaters during off-peak times to level out the load and increase grid efficiency. And in mutually beneficial cases, GMP is helping remote customers go off the grid, eliminating costly line maintenance expenditures for a very small customer base while maintaining customers and broadening electricians’ skillsets by expanding into solar. These customers still pay a monthly fee for their off-grid power [88].

As shown by examples presented above, IOUs strategically incorporating sustainable innovations into their existing competencies are less likely to be disrupted by these innovations. By assessing and identifying where solar energy can be deployed for mutual advantage to themselves and their customers, utilities can be prepared for sustainable innovations and face less disruption.

Research Question 4

4. Does the right environment/culture enable the strategic change needed for a monopoly incumbent firm to adopt sustainable innovations that are potentially disruptive?

Obsessing over the customer in Vermont leads to different ends than it might in other regions of the United States. Customers there help push for the diffusion of renewable energy as a means to retain independence, keep local economies flourishing by recirculating dollars within communities as opposed to paying for power produced outside of the state, while caring for the rich natural environment.

Indeed, the culture in Vermont may be more conducive than that of other states in contributing to the local increase in renewable energy generation. Burlington, VT achieved the distinction of being America's first 100% all renewable energy city. Burlington achieved that goal by 2014, owning the means to its own all-renewable power production. "The beautiful thing is that we do as a general rule to see the common good as a fundamental component of life here," stated Jennifer Green, Burlington's sustainability coordinator, "We all have to give a little for everybody to get some" [114].

Significantly contributing to the current desire for energy independence and attempting to achieve local generation of what it consumes, Vermont's independence has been part of its culture since 1777. That year, Vermont proclaimed itself an autonomous republic and remained so for 14 more years even though during the same year, 1777, it hosted the first significant American victory during the Revolutionary War [115]. The first recorded instance of the Underground Railroad to assist fleeing slaves was in Vermont. It was the third state to grant civil unions for same-sex couples, and same-sex marriage was approved by the legislature as opposed to voters, in 2009. It is the least religious state, with just 33% of Vermonters considering themselves religious [116]. In Vermont politics, independent political candidates have opportunities to succeed because smaller political parties are not subject to elimination as they are in other states. It was the first state to require labeling of genetically modified foods [117].

GMP is a generation and distribution utility, serving 70% of end-users in Vermont [89]. GMP was the first utility in the nation to become certified as a B Corporation, demonstrating its commitment to using economic forces to deal with ecological and community issues [88]. A "B Corporation" is a relatively new for-profit corporate designation which calls special attention to a commitment to environmental and social issues, accountability and transparency [118].

While GMP is a regulated monopoly, arguably not subject to competitive advantage influences in the marketplace, promoting the brand as a sustainable company is important to their customer base and thus something they strive to be. The individuals who work at GMP share the same vision as their CEO [107].

Under atypical leadership for a utility, GMP is poised to embrace change. A mere seven percent of utility Executive Directors in the United States and Canada were women in 2015 [119]. Lacking any advanced, or even 4-year degree, Mary Powell holds an Associate's degree from Keene State College, yet became a visionary CEO [120]. Powell has broken down reporting hierarchy, promoting equality and leadership throughout the organization [121].

As the culture at GMP changed over the last 10 years while Mary Powell served at the helm, the organization continued to innovate. As stated by Stephen Lacey:

> "Mary Powell has a simple mantra: 'Culture eats strategy.' Since taking over as CEO of Green Mountain Power, she's implemented a startup culture that represents a dramatic departure from a traditional utility model – obsessing over the customer, mixing employees in order to uncover new ideas, testing out new products and reimagining the power delivery business model itself" [122].

GMP was listed as the most innovative company in the directory of "Most Innovative Energy Companies" by *Fast Company* in 2018 [107]. In 2019, they will continue to live up to this by addressing the "duck curve" happening in Vermont with the increase in electricity consumption in the evening and the lack of solar energy during those hours, by installing 2,000 utility dispatchable Tesla PowerWall devices for customers who select them [107].

Powell and her team are working to transform the company and the services they provide, while increasing electricity consumption. As parts of its transition to being much more customer-focused, the company moved its headquarters from a sleek, modern glass building, to an approachable, much more energy efficient building located on a reclaimed brownfield. As opposed to many extremely complicated utility bills, GMP has further redesigned theirs to be accessible and user-friendly, with graphs and charts that make it easy to comprehend.

> "How do we lead and accelerate the customer-led revolution to DG that we want to see happen?" *GMP CEO Mary Powell*

GMP has the needed environment and culture required in order to incorporate sustainable innovations. Focus on the customer and a visionary CEO have led changes from customer-friendly simplification of power bills to the incorporation of energy storage. With a unique leader possessing a pioneering mindset, and a culture that encourages innovation, GMP has been winning awards for their innovation. By virtue of their location, GMP has the added advantage of being supported by the independent culture of Vermont.

Research Question 5

5. Is a monopoly incumbent able to recognize and pursue new market opportunities arising out of a sustainable innovation instead of viewing it as disruptive more likely to contribute to the successful diffusion of such innovation?

Monopolies are challenged by adopting new strategies for conducting business [70]. Not only are incumbents faced with the challenge of learning from innovations in the deregulated marketplace, they must also unlearn strategies which relied on the former dominant paradigm [123] [124] [125]. An example of an electric utility that is actively pursuing new opportunities, GMP has identified market opportunities that will advance the company's goals while incorporating sustainable innovations and contributing to their diffusion. GMP is doing this in a variety of avenues, working actively to deploy the most impactful sustainable innovations.

One of Christensen's tenets that incumbents must address with new technology is that their greatest value in the emerging market makes the technology unattractive in the incumbent market. Even though solar energy in the U.S. today is primarily used in grid-interactive applications, it started out being used in remote and off-grid markets. Being very expensive as compared to other electricity sources, it was unattractive in the incumbent market. Utilities would not deploy the technology as they saw little use for it. . Yet, GMP saw an opportunity to apply solar with storage considering its emerging market value.

GMP has identified market opportunities that will advance the company's goals while incorporating sustainable innovations and contributing to their diffusion. Specifically, they are converting some stranded customers from grid electricity to off-grid solar energy systems. They anticipate that by incorporating this strategy into their electricity service delivery model where small consumers require significant grid maintenance, the result will be significant savings. GMP conducted an evaluation of its current distribution infrastructure and noticed numerous stranded assets around the State of Vermont. Some of these assets made the utility suffer an economic loss due to maintenance required, and the modest revenue associated with the asset did not offset all of the maintenance and other associated expenses. In these instances, GMP is helping their customers at the end of the power line to go solar with energy storage, continuing to charge a monthly fee for the electric service. GMP is taking the emerging market value of energy independence for solar and energy storage, and applying it to their own business model.

Additionally, GMP will be incorporating energy storage into their utility service model in 2019, deploying two thousand PowerWall systems throughout their territory. Maintaining control of the energy storage systems will facilitate the capture of solar power and release of that power during peak times, allowing greater stability and increasing the amount of renewable power they are able to utilize [107].

In 2007, a Canadian company called Gaz Metro acquired GMP. Further restructuring occurred during a merger between Central Vermont Public Service Corporation and GMP in 2012 when the former was acquired by Gaz Metro, making GMP the largest electric utility in Vermont [126] [107]. In 2018, Gaz Metro was rebranded as Energir. In addition to other companies in its energy portfolio, in March 2017, it purchased a solar energy developer and EPC called Standard Solar [127].

Customer input helps to guide GMP decisions. According to CEO Mary Powell, GMP customers wanted to be more energy independent, generating electricity in Vermont as opposed to having 75% of their electricity imported. Providing energy that is over 60% renewable, from hydro, wind and solar, GMP recently also acquired 12 local hydro plants, bringing their total local hydro plant ownership to 44, the bulk of which are located in Vermont [88].

The business has been redefined from one that simply delivers power to one that serves customers and is very customer-focused. This transition is key for an industry traditionally focused more on assets and trading than concern for customers' desires. Yet at GMP, CEO Mary Powell's voice is recorded on their voicemail, and she assures anyone choosing to leave a message that they will receive a response within 24 hours. Indeed, when the author skeptically left a message on the voicemail, a response was received in less than 24 hours.

GMP has significantly contributed to the diffusion of solar energy in Vermont, and successfully recognized new market opportunities arising out of the incorporation of sustainable innovations. For instance, GMP is transitioning costly stranded customers into off-grid renewable energy systems, and incorporating energy storage. GMP demonstrates that monopoly incumbents able to recognize and successfully pursue new market opportunities arising from sustainable innovations are more likely to contribute to the successful diffusion of that innovation.

4.3 Summary

Through the case study of Green Mountain Power, the five research questions were investigated individually. Reflecting existing research which waffles with identifying the optimal level of competition required in order to promote innovation, for research question 1, the case study showed that natural monopolies can be effective organizations to promote sustainable innovations given the right conditions.

To answer research question 2, among the many factors that contribute to the right conditions, regulation is the most critical one as opposed to market forces in the monopoly market. This was clearly shown by the actual deployed solar in GMP service territory following regulatory events illustrated in Figure 10. Compared to other regional utilities, GMP has 3.5 times greater solar penetration. While there were certainly other factors at play, including the ability of GMP to initially sell associated RECs to neighboring states at significant profit, policies such as increases in net metering caps and favorable net metering rates appear to have directly impacted diffusion.

For research question 3, GMP has pursued collaboration with outside parties to resolve technical challenges, developed unique partnerships, established a culture of continuous improvement, placed an emphasis on customer service, and put an innovative leader at the helm. Recognizing the changing landscape for utilities, they are adapting and conforming to strategically incorporate sustainable innovations.

Both Vermont and Green Mountain Power culture support new ideas, which are critical of the status quo. The Vermont culture values energy independence, and the GMP culture features innovative perspective and customer focus. The cultural characteristics required in order to adopt sustainable innovations that could be viewed as disruptive are present, which partly answers the research question 4.

Finally, GMP has been able to recognize and pursue new market opportunities through embracing sustainable innovations, rather than viewing them with suspicion. In part, this has led them to successfully incorporate the sustainable innovations, and thereby contribute to their diffusion.

5.0 Conclusion

Renewables will comprise an increasing proportion of worldwide electricity supply. The integration of these power sources into existing grids will be required in order to achieve the high levels forecasted. Technical hurdles can be overcome, yet will result in additional integration costs. These technical barriers include uncertainty, locational specificity, and variability. [128]

Setting up protected spaces through policy framework, economic incentives, and so on, are methods used for regulation to introduce societally desirable marketplace changes. Innovations generating disruptions in monopolies are frequently caused by regulation, often leading to partial disruption and not a replacement of all technological competencies. The movement of natural regulated monopolies in any direction is driven by regulation. Legislation and regulation are key factors in getting natural monopolies to adopt sustainable innovations. In the case studies where monopolies changed, the change was driven by regulation.

In the regulated monopoly situation, the monopoly will still be the one most likely to win provided they conform their business with existing competence. Therefore, understanding, articulating, and acting upon a firm’s core strengths is of critical importance when facing a disruption. While distributed generation adds electrons to the grid, it does not take the place of many existing core competencies in electric service delivery. As utilities move into the future electricity markets, it will be important to determine which core competencies will need to be sustained, and which should be overhauled or eliminated. The case study demonstrated clear examples of a company able to identify core strengths when facing a disruption, and utilize those strengths to move into a new technological era.

Specific suggestions generated from this study for government and utility companies to diffuse renewable energy include:

1. Recognize that utilities, as natural monopolies, can be effective adopters in the diffusion of distributed generation given the right policies and incentives;
2. Consider regulations carefully and create the right ones to diffuse renewable energy. Regulation plays a critical role in the diffusion of renewable energy in the natural monopoly, as opposed to market forces;
3. Utilities should evaluate their core competencies, such as wheeling electricity, electricity generation and distribution, and customer management, and focus on their continued improvement in order to prevent grid defection and the utility death spiral;
4. Utilities should consider the industry changes which are rapidly approaching, and understand how they can develop a culture of adaptation and innovation to help them move forward;

5. Utilities can embrace innovations and evaluate ways in which they might incorporate renewable energy into their service delivery model, which could save resources and improve their bottom line.

Based on literature review and through a case on a successful innovator in the U.S. utility industry, this work attempted to identify factors that promote sustainable innovations' diffusion using the electricity generation from solar energy as the example. Unique factors impacting the adoption of sustainable innovations in monopoly markets such as the electric utilities were identified. As a result, a list of questions was generated as a checklist for utility companies that are interested in adopting and promoting sustainable innovations.

As only one case study was selected in this nascent industry, it is not necessarily representative for industries in other locales or in other situations. Therefore, results may not be translatable for others who don't successfully incorporate sustainable innovations. Further, this research was focused on investor-owned utilities. Future work might expand to examine other utility structures, such as municipal utilities or cooperative utilities. The size of a utility in its ability to incorporate sustainable innovations was also not considered, and may be a significant factor. Future work might also clearly identify the most important factors in increasing the diffusion of solar energy. Of the options, the greatest factor impacting the successful incorporation of solar energy into the Vermont electricity generation mix was not identified, with regulation, cost per Watt, and return on investment all being factors.

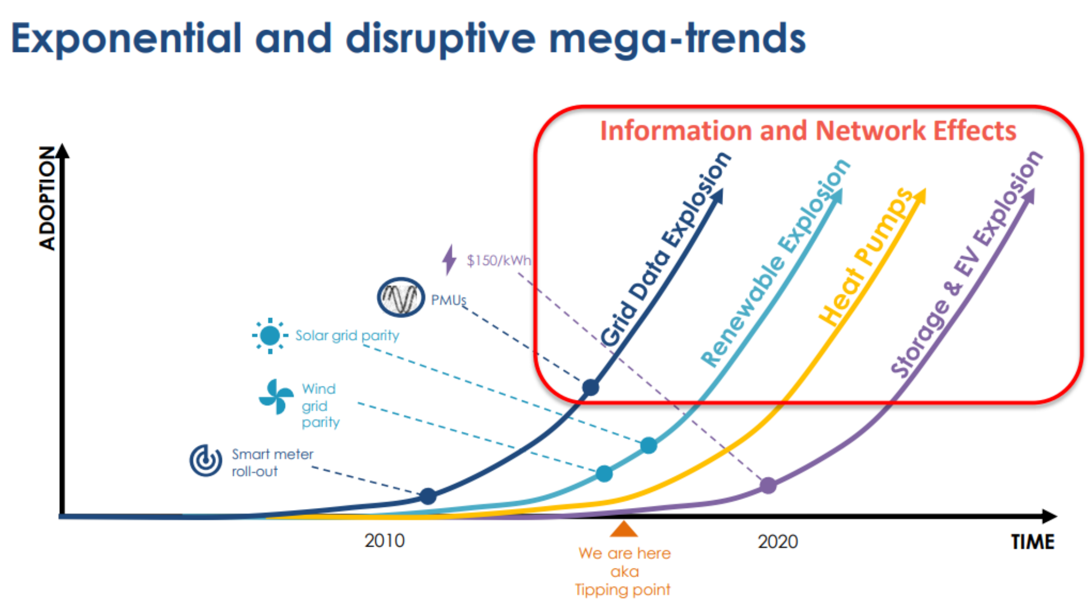

Figure 11: Trends according to OSIsoft [129]

Change is coming to the incumbent utility industry around the world. If utilities do not evolve, they could increasingly find customers cutting themselves off the grid as energy storage experiences technical and economic improvements. As shown in Figure 11, adoption rates of energy storage are anticipated to significantly increase in the very near future as the technology continues to evolve. Grid stability and reliable electricity supply are still very important to consumers, and utilities have considerable experience in supplying these. Evaluating and exploiting other key competences will be an important first step as their role in the market evolves. Utilities without a realistic plan for incorporating changes will struggle.

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